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A NOTE ON SPECIALIZED VERSUS UNSPECIALIZED METHODS FOR MAXIMUM --ETC(U)
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(6) A NOTE ON SPECIALIZED VERSUS UNSPECIALIZED
7 METHODS FOR MAXIMUM FLOW PROBLEMS

by

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A study developing highly efficient versions of both primal simplex and labeling methods for maximum flow problems has disclosed the surprising superiority of specialized primal methods, [1]. Recently another study by Grigoriadis and Hsu [2] has compared an unspecialized primal method (designed for general minimum cost flow problems but tuned in terms of having special subroutines to exploit maximum flow problem characteristics) to classical labeling techniques and has found this *unspecialized* method likewise to be superior to the more popular *specialized* approaches. These provocative findings not only overturn standard expectation about the relative performance of simplex versus labeling approaches, but also raise the intriguing question of whether--or to what extent--it is useful to develop specialized methods for maximum flow problems.

Accordingly, we have undertaken to investigate this issue was investigated by testing both specialized and unspecialized primal simplex codes on the same maximum flow problems using the same computer and compiler. Considering the possibility that some general primal network codes may be better tuned to maximum flow applications than others, ~~we obtained the~~ a code was obtained ~~of [2] (courtesy of Michael Grigoriadis)~~ which ~~has~~ was ~~been~~ timed for maximum flow problems in terms of using a special tree orientation, pricing subroutine, and pivot selection subroutine. (We slightly modified this code to correct a minor bug ~~in its pri~~cing routine for maximum flow problems.) The specialized primal code used in ~~our~~ the tests is the SEQCS code, ~~described in [1].~~ Hereafter ~~we will~~ it is, next page respectively, refer to these codes as GENERAL and SPECIAL.

~~Our~~ tests of the two methods ~~have been~~ were conducted on four types of network structures: random (R), multi-terminal random (MR), transit grid (TG), and hard (H). ~~We~~ It is found after testing 185 maximum flow problems embodying these diverse structures that the SPECIAL code is substantially more efficient than GENERAL, in spite of the fact that GENERAL ~~has been~~ was demonstrated superior to the specialized maximum flow procedures it was previously tested against. The basis for these findings and more refined conclusions follow.

The R problems were generated by randomly selecting ordered node pairs to identify the arcs (avoiding duplication), and these were in turn randomly assigned capacities from a predefined interval. The source node and sink node were also selected randomly. The MR problems were generated similarly, except that infinite capacities are assigned to all arcs meeting the source node and sink node, thereby converting adjacent nodes into effective sources and effective sinks. The TG problems, which embody a structure often found in transportation applications, also include this multi-terminal construction, but all nodes other than the source and sink are "grid" nodes which can be viewed as arranged in a rectangular grid of r rows and c columns. Each adjacent pair of grid nodes is connected by two oppositely directed arcs whose capacities are selected from a predefined interval. Finally, the H problems consist of fully dense acyclic networks constructed in such a manner that the optimal solution can only be obtained when every arc receives a flow equal to its capacity, thereby generally requiring a large number of iterations (starting from a zero flow state). Fuller details of these problems and their generation may be found in [1].

For our tests, five different problems were generated from each of several sets of problem dimensions for each of the problem classes. Twelve problem dimensions, R1, ..., R12 and MR1, ..., MR12 were selected for the R and MR problems, while eight problem dimensions, TG1, ..., TG8, and five problem dimensions, H1, ..., H5, were selected for the TG and H problems. Relevant parameters appear in Tables I, II, III, and IV.

All computer runs were carried out on the Dual Cyber 170/175 using the MNF FORTRAN compiler during periods of comparable computer use. A total of 185 problems were tested. The results, recorded in Table V, provide median solution times for each group of five problems with the same dimensions from a given class. GENERAL was run using five different pivot strategies. The pivot strategies tested varied in the pricing frequency used for each pass through the arc list. This is controlled by the user-supplied parameter, FRQ, in GENERAL. The heading in Table V indicates the value used for this parameter (e.g., GENERAL 1 means FRQ = 1).

As Table V demonstrates, the value of developing a sophisticated specialization for maximum flow problems is clear. The SPECIAL method is uniformly superior to the GENERAL method by a factor ranging from 20% on the MR problems, to 200% on the grid problems. Overall SPECIAL is approximately 80% faster than the best GENERAL, GENERAL 5. Since SPECIAL requires less computer memory and its times are notably better, it appears worthwhile developing totally specialized primal simplex codes for applications requiring repeated solution of maximum flow problems.

TABLE I

RANDOM PROBLEM SPECIFICATIONS

PROBLEM	|N|	|A|	ARC CAPACITY RANGE
R1	250	1250	1-100
R2	250	1875	1-100
R3	250	2500	1-100
R4	500	2500	1-100
R5	500	3750	1-100
R6	500	5000	1-100
R7	750	3750	1-100
R8	750	5825	1-100
R9	750	7500	1-100
R10	1000	5000	1-100
R11	1000	7500	1-100
R12	1000	10000	1-100

TABLE II

MULTI-TERMINAL RANDOM PROBLEM SPECIFICATIONS

PROBLEM	|N|*	|A|	AVERAGE NO. OF ARCS INCIDENT ON EACH MASTER SOURCE (TERMINAL)	ARC CAPACITY RANGE**
MR1	250	1250	5.0	1-100
MR2	250	1875	7.5	1-100
MR3	250	2500	10.0	1-100
MR4	500	2500	5.0	1-100
MR5	500	3750	7.5	1-100
MR6	500	5000	10.0	1-100
MR7	750	3750	5.0	1-100
MR8	750	5825	7.5	1-100
MR9	750	7500	10.0	1-100
MR10	1000	5000	5.0	1-100
MR11	1000	7500	7.5	1-100
MR12	1000	10000	10.0	1-100

* There were five master source nodes and five master terminal nodes.

** Excluding arcs entering or leaving source and terminal nodes.

TABLE III

TRANSIT GRID PROBLEM SPECIFICATIONS

PROBLEM	$\|N\|$*	$\|A\|$	AVERAGE NO. OF ARCS INCIDENT ON EACH MASTER SOURCE (TERMINAL)	ARC CAPACITY RANGE**
TG1	235	1240	40	1-100
TG2	235	1640	80	1-100
TG3	410	2120	60	1-100
TG4	410	2720	120	1-100
TG5	635	3200	80	1-100
TG6	635	4000	160	1-100
TG7	910	4480	100	1-100
TG8	910	5480	200	1-100

* Including five master source nodes and five master terminal nodes.

** Excluding arcs entering or leaving master source and master terminal nodes.

TABLE IV

HARD PROBLEM SPECIFICATIONS

PROBLEM	$\|N\|$	$\|A\|$	ARC CAPACITY RANGE
H1	20	190	1-82
H2	40	780	1-362
H3	60	1770	1-782
H4	80	3160	1-1522
H5	100	4950	1-2402

TABLE V
COMPUTER TIMES* IN SECONDS FOR MAXIMUM FLOW PROBLEMS
ON A DUAL CYBER 170/175 USING MNF COMPILER

PROBLEMS	SPECIAL	GENERAL 20	GENERAL 10	GENERAL 5	GENERAL 2	GENERAL 1
R1	.04	.12	.12	.12	.18	.26
R2	.07	.21	.16	.17	.22	.31
R3	.08	.16	.17	.18	.22	.31
R4	.07	.24	.25	.27	.38	.54
R5	.16	.35	.35	.34	.43	.61
R6	.24	.40	.35	.35	.48	.69
R7	.12	.38	.35	.42	.55	.81
R8	.22	.44	.45	.46	.66	.89
R9	.40	.67	.57	.60	.71	.98
R10	.21	.50	.54	.53	.77	1.08
R11	.32	.65	.66	.67	.89	1.18
R12	.46	.83	.78	.84	.99	1.34
TOTAL	2.39	4.95	4.75	4.95	6.48	9.00
MR1	.11	.24	.20	.19	.26	.36
MR2	.25	.50	.41	.39	.43	.55
MR3	.25	.36	.36	.35	.39	.49
MR4	.13	.33	.31	.35	.39	.59
MR5	.38	.51	.63	.44	.58	.76
MR6	.67	1.09	.81	.72	.73	1.00
MR7	.30	.53	.56	.46	.67	.90
MR8	.45	.67	.57	.57	.77	1.07
MR9	1.11	2.45	1.50	1.33	1.22	1.52
MR10	.32	.82	.62	.66	.89	1.24
MR11	.86	1.16	1.06	1.12	1.22	1.49
MR12	1.67	2.14	1.89	1.64	1.43	1.73
TOTAL	6.50	10.80	8.92	8.22	7.76	11.70
H1	.03	.06	.06	.08	.11	.17
H2	.20	.43	.45	.51	.59	.87
H3	.66	1.50	1.51	1.37	1.88	2.50
H4	1.53	3.97	3.44	3.23	3.96	4.85
H5	2.96	7.58	6.54	6.12	7.61	9.27
TOTAL	5.38	13.54	12.00	11.31	14.15	17.66
TG1	.09	.21	.19	.24	.30	.44
TG2	.08	.20	.18	.23	.33	.46
TG3	.21	.39	.39	.42	.56	.85
TG4	.18	.35	.39	.40	.56	.85
TG5	.35	.64	.64	.67	.89	1.31
TG6	.27	.57	.58	.61	.82	1.24
TG7	.43	.89	.88	.93	1.14	1.70
TG8	.51	.96	.89	.99	1.25	1.93
TOTAL	2.12	4.21	4.14	4.49	5.85	8.78
GRAND TOTAL	16.39	33.50	29.81	28.97	34.24	47.14

*Five problems of each type were solved and the solution time reported in seconds.

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1. F. Glover, D. Klingman, J. Mote, and D. Whitman, "Comprehensive Computer Evaluation and Enhancement of Maximum Flow Algorithms." Research Report CCS 356, Center for Cybernetic Studies, The University of Texas at Austin, 1979.

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